


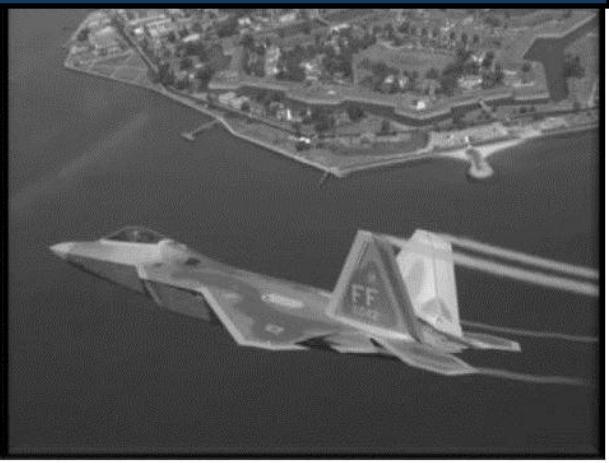


Economic Drivers of Strategic & Critical Materials

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DLA- Strategic Materials

Report Documentation Page

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Overview - Megatrends

- Major “disruptions” to the global economy and social fabric have implications for material requirements
- Examples:
  - Miniaturization and Light-weighting
  - Processing speed
  - Social Networking
  - Additive “social” manufacturing
  - Greening of the economy

Miniaturization & Light-Weighting

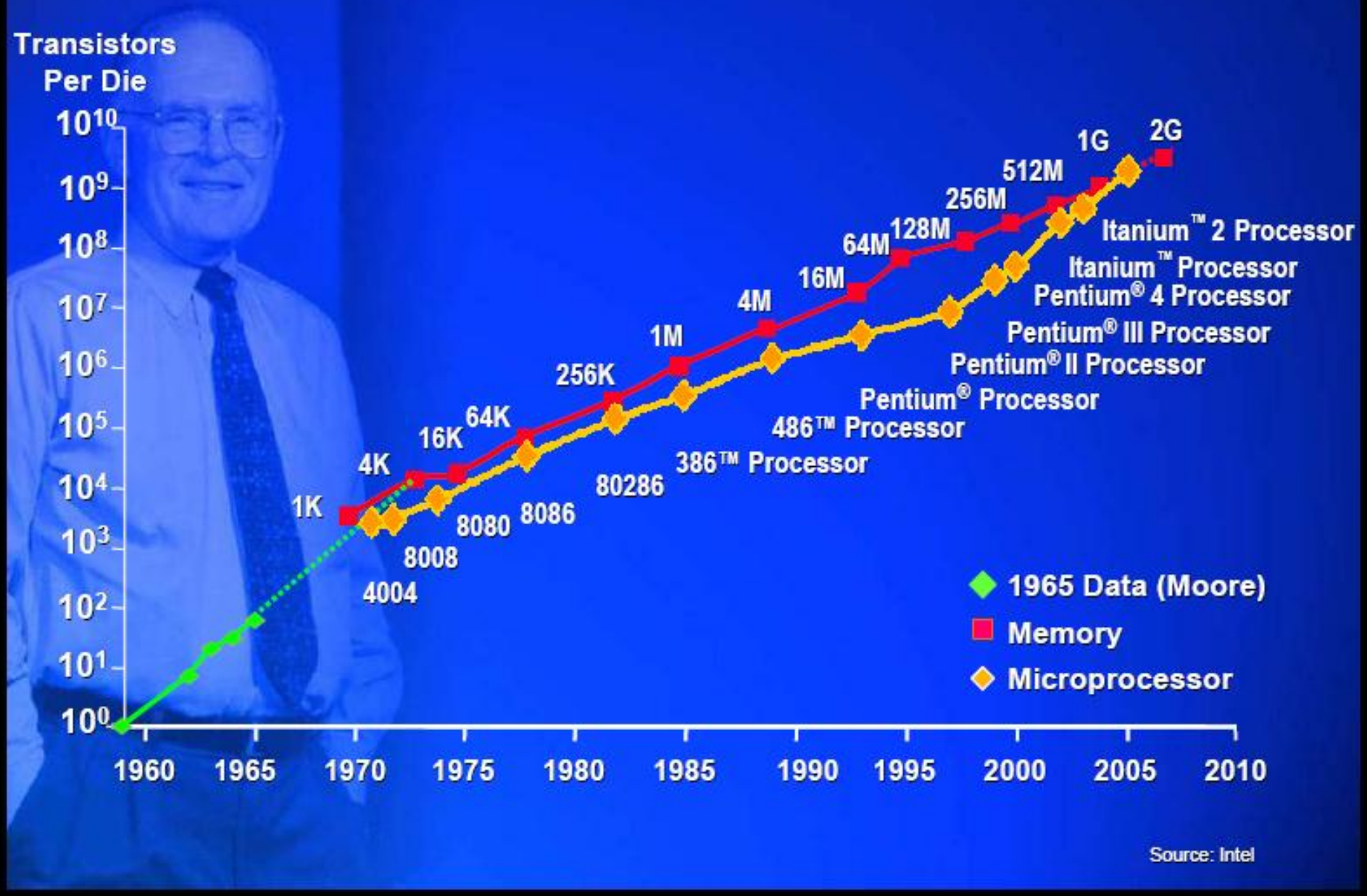
Weight: 2.5 lbs

Dimensions: 9” x 5” x 1.7”

Weight: 140 grams

Dimensions: 4.33″ x 2.36″ x .27″

Moore's Law - 2005



Social Networking

Greening of the Economy

Implications for Technological Change

- Change the way society is organized
- Affect the way we interact with one another
- Transform the way we do business
- Alter the way we take part in leisure
- Have profound impact on access to information
- Can be a force for democracy and openness
  - And also their opposites
- Alters the way humans perceive what is "current"

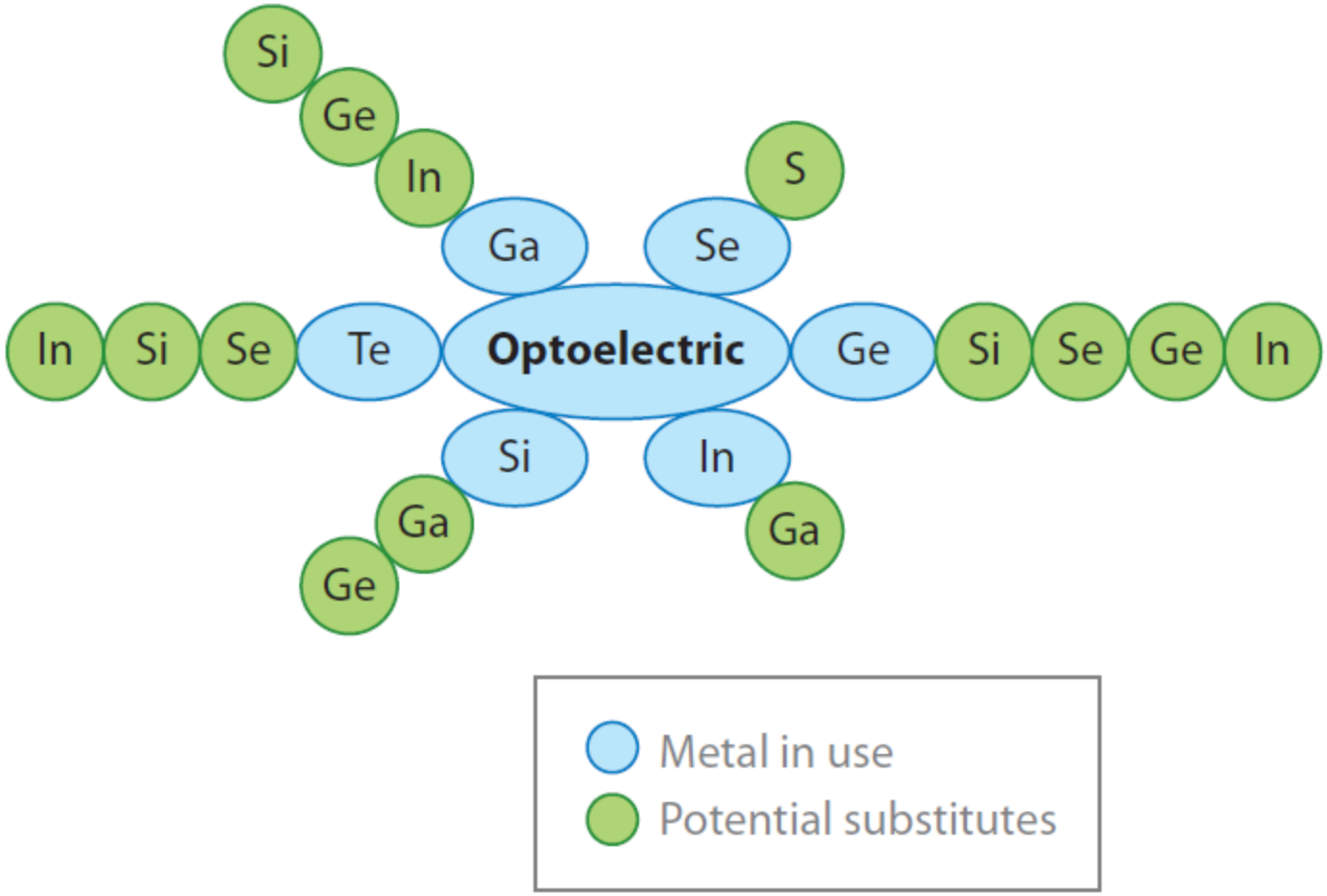
Some Variables that Matter

1. Growth rate of the material's end-uses
2. Intensity of use (e.g. quantity per person, quantity per dollar)
3. Availability and performance of substitutes
4. Technology deployment and penetration
5. Scale-up
6. Import vulnerability
7. Parent/Daughter metals
8. Market concentration
9. Social, political, environmental, regulatory and governance
10. Crustal abundance and form of mineralization
    1. Cost of exploration and extraction
11. Energy costs
12. Business strategy

Substitutes

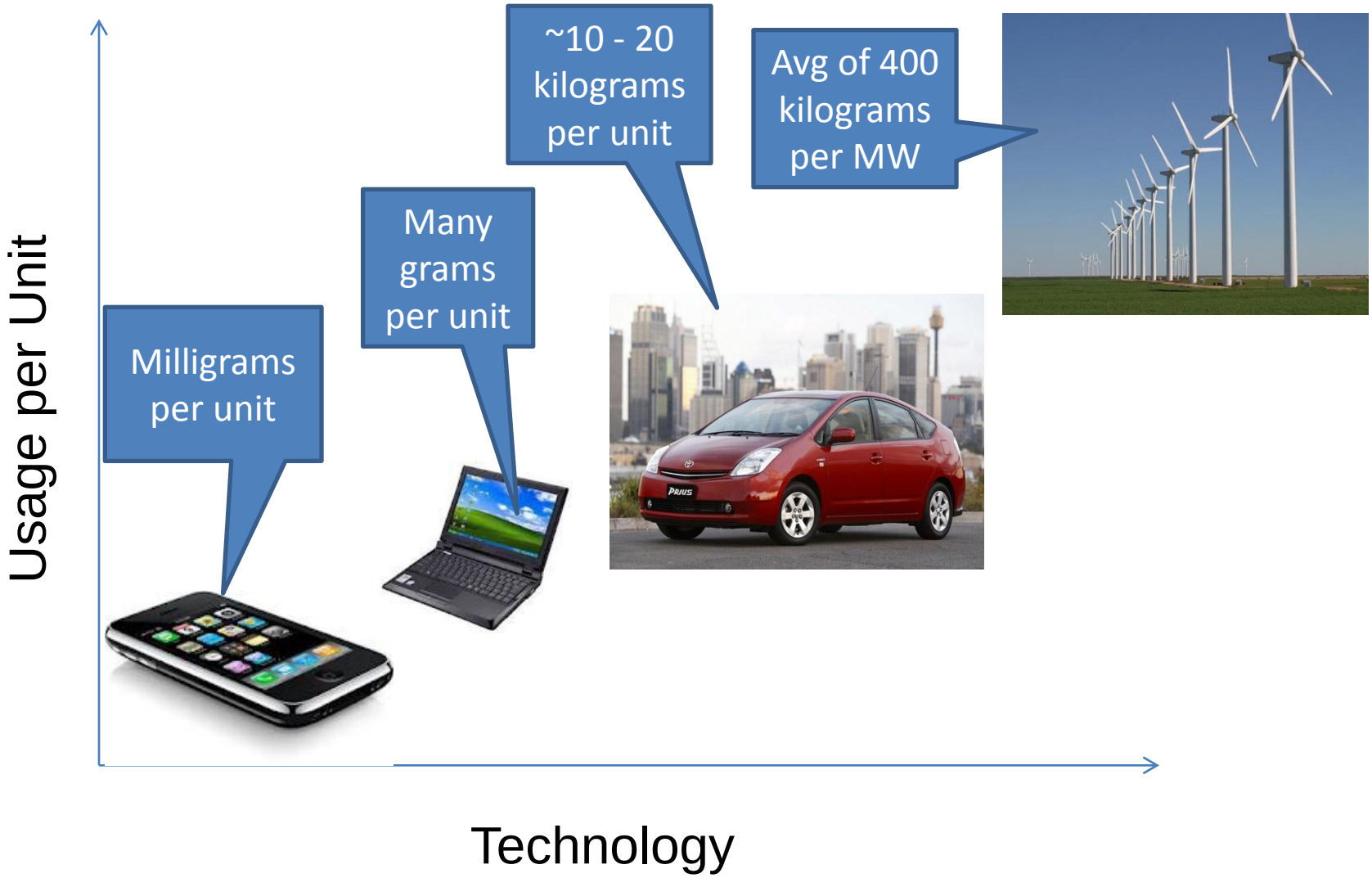
- Many high tech materials lack readily available, cost-effective substitutes
  - And typically are daughter elements of the existing parent element currently in use
- Substitution often requires re-engineering of not only the product but the entire supply chain
- Substitution requires re-testing and re-certification
- Substitution is expensive and is best thought of a long-term solution requiring significant R&D expenditure
  - But, we can't just wait for the long-term to arrive. Successful companies are acting now so substitute materials are researched, tested, and commercialized

The Flower of Potential Substitution Involves Supply Issues of Their Own



Source: Professor Graedel courtesy of Umicore

Rare Earth Scale-up Example



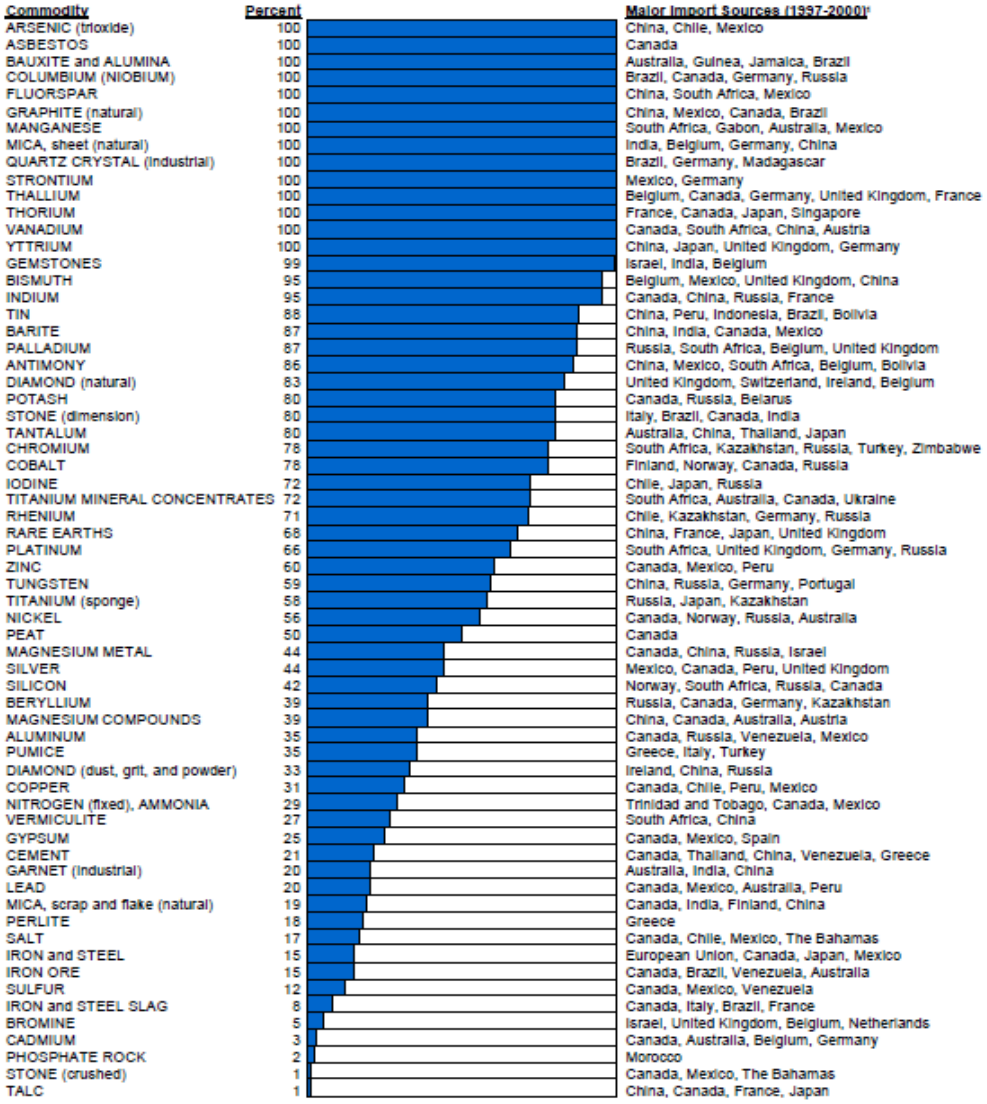
USGS Import Dependence - 2011

2011 U.S. NET IMPORT RELIANCE FOR SELECTED NONFUEL MINERAL MATERIALS

Commodity	Percent	Major Import Sources (2007–10)[1]
ARSENIC (trioxide)	100	Morocco, China, Belgium
ASBESTOS	100	Canada, Zimbabwe
BAUXITE and ALUMINA	100	Jamaica, Brazil, Guinea, Australia
CESIUM	100	Canada
FLUORSPAR	100	Mexico, China, South Africa, Mongolia
GRAPHITE (natural)	100	China, Mexico, Canada, Brazil
INDIUM	100	China, Canada, Japan, Belgium
MANGANESE	100	South Africa, Gabon, China, Australia
MICA, sheet (natural)	100	China, Brazil, Belgium, India
NIOBIUM (columbium)	100	Brazil, Canada, Germany, Russia
QUARTZ CRYSTAL (industrial)	100	China, Japan, Russia
RARE EARTHS	100	China, France, Estonia, Japan
RUBIDIUM	100	Canada
SCANDIUM	100	China
STRONTIUM	100	Mexico, Germany
TANTALUM	100	China, Germany, Kazakhstan, Australia
THALLIUM	100	Russia, Germany, Kazakhstan
THORIUM	100	France, India, Canada, United Kingdom
YTTRIUM	100	China, Japan, France, United Kingdom
GALLIUM	99	Germany, Canada, United Kingdom, China
IODINE	99	Chile, Japan
GEMSTONES	98	Israel, India, Belgium, South Africa
GERMANIUM	90	China, Belgium, Russia, Germany
BISMUTH	89	China, Belgium, United Kingdom,
DIAMOND (dust, grit and powder)	89	China, Ireland, Republic of Korea, Russia
PLATINUM	88	Germany, South Africa, United Kingdom, Canada
ANTIMONY	87	China, Mexico, Belgium
RHENIUM	87	Chile, Netherlands, Germany
STONE (dimension)	85	Brazil, China, Italy, Turkey
POTASH	83	Canada, Belarus, Russia
VANADIUM	80	Rep. of Korea, Canada, Austria, Czech Republic
BARITE	78	China, India
SILICON CARBIDE	76	China, Brazil, Vietnam, Norway
TIN	76	Peru, Bolivia, Indonesia, China
COBALT	75	China, Norway, Russia, Canada
SILVER	75	Mexico, Canada, Peru, Chile
ZINC	73	Canada, Peru, Mexico, Ireland
TITANIUM (sponge)	69	Kazakhstan, Japan, China, Russia
TITANIUM MINERAL CONCENTRATES	68	South Africa, Australia, Canada, Mozambique
PEAT	63	Canada
CHROMIUM	60	South Africa, Kazakhstan, Russia, China
PALLADIUM	56	Russia, South Africa, United Kingdom, Norway
MAGNESIUM COMPOUNDS	53	China, Canada, Brazil, Austria
NICKEL	47	Canada, Russia, Australia, Norway
SILICON (ferrosilicon)	42	China, Russia, Venezuela, Canada
NITROGEN (fixed), AMMONIA	41	Trinidad and Tobago, Russia, Canada, Ukraine
GARNET (industrial)	39	India, Australia, China, Canada
GOLD	36	Mexico, Canada, Colombia, Peru
TUNGSTEN	36	China, Bolivia, Canada, Germany
COPPER	35	Chile, Canada, Peru, Mexico
MAGNESIUM METAL	35	Israel, Canada, China
PERLITE	27	Greece
SULFUR	24	Canada, Mexico, Venezuela
SALT	22	Canada, Chile, Mexico, The Bahamas
BERYLLIUM	21	Russia, Kazakhstan, Japan, Russia
MICA, scrap and flake (natural)	20	Canada, China, India
VERMICULITE	20	China, South Africa, Australia, Brazil
ALUMINUM	13	Canada, Russia, China, Mexico
GYPSUM	13	Canada, Mexico, Spain
PHOSPHATE ROCK	13	Morocco, Peru
IRON and STEEL	9	Canada, European Union, China, Mexico
IRON and STEEL SLAG	8	Japan, Canada, South Africa, Italy
CEMENT	6	Canada, China, Republic of Korea, Mexico
PUMICE	5	Greece, Mexico, Iceland, Montserrat
DIAMOND (natural industrial stone)	3	Botswana, South Africa, Russia, Namibia
LIME	1	Canada, Mexico
STONE (crushed)	1	Canada, Mexico, The Bahamas

USGS Import Dependence - 2001

2001 U.S. NET IMPORT RELIANCE FOR SELECTED NONFUEL MINERAL MATERIALS



Commodity	Percent	Major Import Sources (1997-2000)[1]
ARSENIC (trioxide)	100	China, Chile, Mexico
ASBESTOS	100	Canada
BAUXITE and ALUMINA	100	Australia, Guinea, Jamaica, Brazil
COLUMBIUM (NIOBIUM)	100	Brazil, Canada, Germany, Russia
FLUORSPAR	100	China, South Africa, Mexico
GRAPHITE (natural)	100	China, Mexico, Canada, Brazil
MANGANESE	100	South Africa, Gabon, Australia, Mexico
MICA, sheet (natural)	100	India, Belgium, Germany, China
QUARTZ CRYSTAL (industrial)	100	Brazil, Germany, Madagascar
STRONTIUM	100	Mexico, Germany
THALLIUM	100	Belgium, Canada, Germany, United Kingdom, France
THORIUM	100	France, Canada, Japan, Singapore
VANADIUM	100	Canada, South Africa, China, Austria
YTTRIUM	100	China, Japan, United Kingdom, Germany
GEMSTONES	99	Israel, India, Belgium
BISMUTH	95	Belgium, Mexico, United Kingdom, China
INDIUM	95	Canada, China, Russia, France
TIN	88	China, Peru, Indonesia, Brazil, Bolivia
BARITE	87	China, India, Canada, Mexico
PALLADIUM	87	Russia, South Africa, Belgium, United Kingdom
ANTIMONY	86	China, Mexico, South Africa, Belgium, Bolivia
DIAMOND (natural)	83	United Kingdom, Switzerland, Ireland, Belgium
POTASH	80	Canada, Russia, Belarus
STONE (dimension)	80	Italy, Brazil, Canada, India
TANTALUM	80	Australia, China, Thailand, Japan
CHROMIUM	78	South Africa, Kazakhstan, Russia, Turkey, Zimbabwe
COBALT	78	Finland, Norway, Canada, Russia
IODINE	72	Chile, Japan, Russia
TITANIUM MINERAL CONCENTRATES	72	South Africa, Australia, Canada, Ukraine
RHENIUM	71	Chile, Kazakhstan, Germany, Russia
RARE EARTHS	68	China, France, Japan, United Kingdom
PLATINUM	66	South Africa, United Kingdom, Germany, Russia
ZINC	60	Canada, Mexico, Peru
TUNGSTEN	59	China, Russia, Germany, Portugal
TITANIUM (sponge)	58	Russia, Japan, Kazakhstan
NICKEL	56	Canada, Norway, Russia, Australia
PEAT	50	Canada
MAGNESIUM METAL	44	Canada, China, Russia, Israel
SILVER	44	Mexico, Canada, Peru, United Kingdom
SILICON	42	Norway, South Africa, Russia, Canada
BERYLLIUM	39	Russia, Canada, Germany, Kazakhstan
MAGNESIUM COMPOUNDS	39	China, Canada, Australia, Austria
ALUMINUM	35	Canada, Russia, Venezuela, Mexico
PUMICE	35	Greece, Italy, Turkey
DIAMOND (dust, grit, and powder)	33	Ireland, China, Russia
COPPER	31	Canada, Chile, Peru, Mexico
NITROGEN (fixed), AMMONIA	29	Trinidad and Tobago, Canada, Mexico
VERMICULITE	27	South Africa, China
GYPSUM	25	Canada, Mexico, Spain
CEMENT	21	Canada, Thailand, China, Venezuela, Greece
GARNET (industrial)	20	Australia, India, China
LEAD	20	Canada, Mexico, Australia, Peru
MICA, scrap and flake (natural)	19	Canada, India, Finland, China
PERLITE	18	Greece
SALT	17	Canada, Chile, Mexico, The Bahamas
IRON and STEEL	15	European Union, Canada, Japan, Mexico
IRON ORE	15	Canada, Brazil, Venezuela, Australia
SULFUR	12	Canada, Mexico, Venezuela
IRON and STEEL SLAG	8	Canada, Italy, Brazil, France
BROMINE	5	Israel, United Kingdom, Belgium, Netherlands
CADMIUM	3	Canada, Australia, Belgium, Germany
PHOSPHATE ROCK	2	Morocco
STONE (crushed)	1	Canada, Mexico, The Bahamas
TALC	1	China, Canada, France, Japan

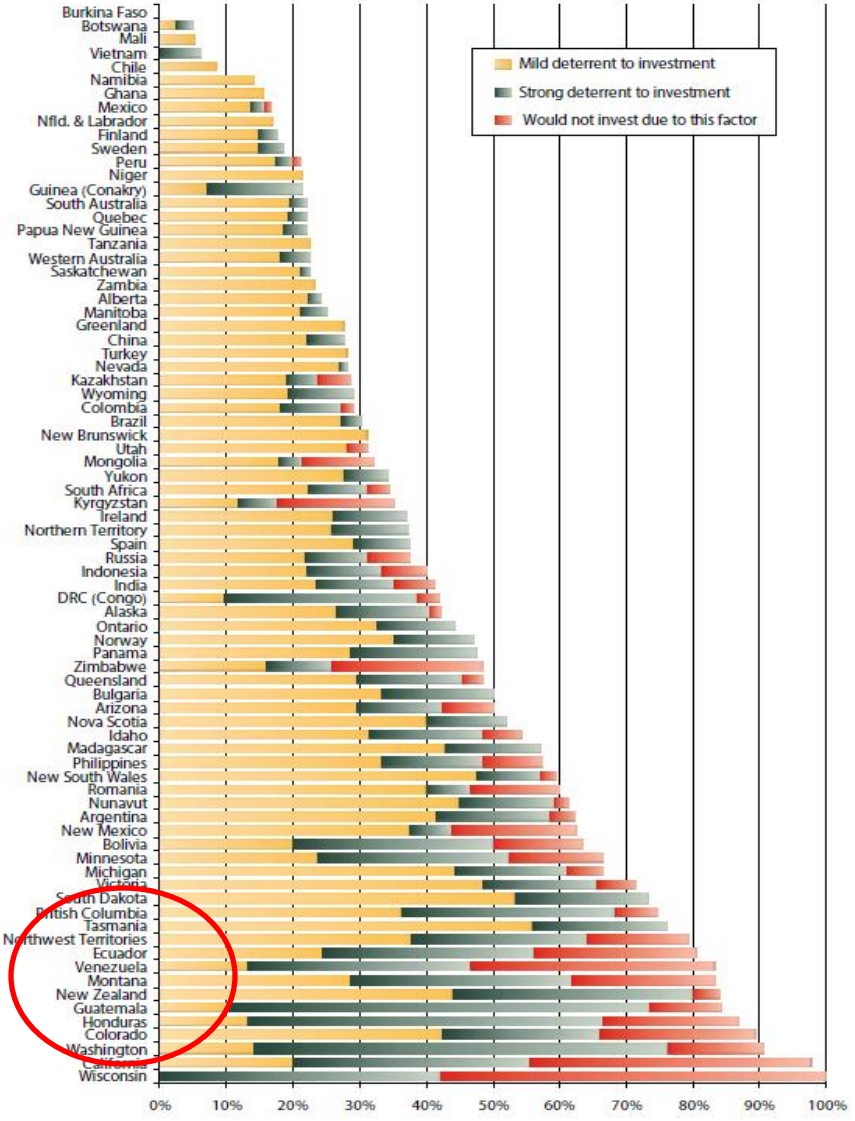
[1]In descending order of import share

Dependence vs. Vulnerability

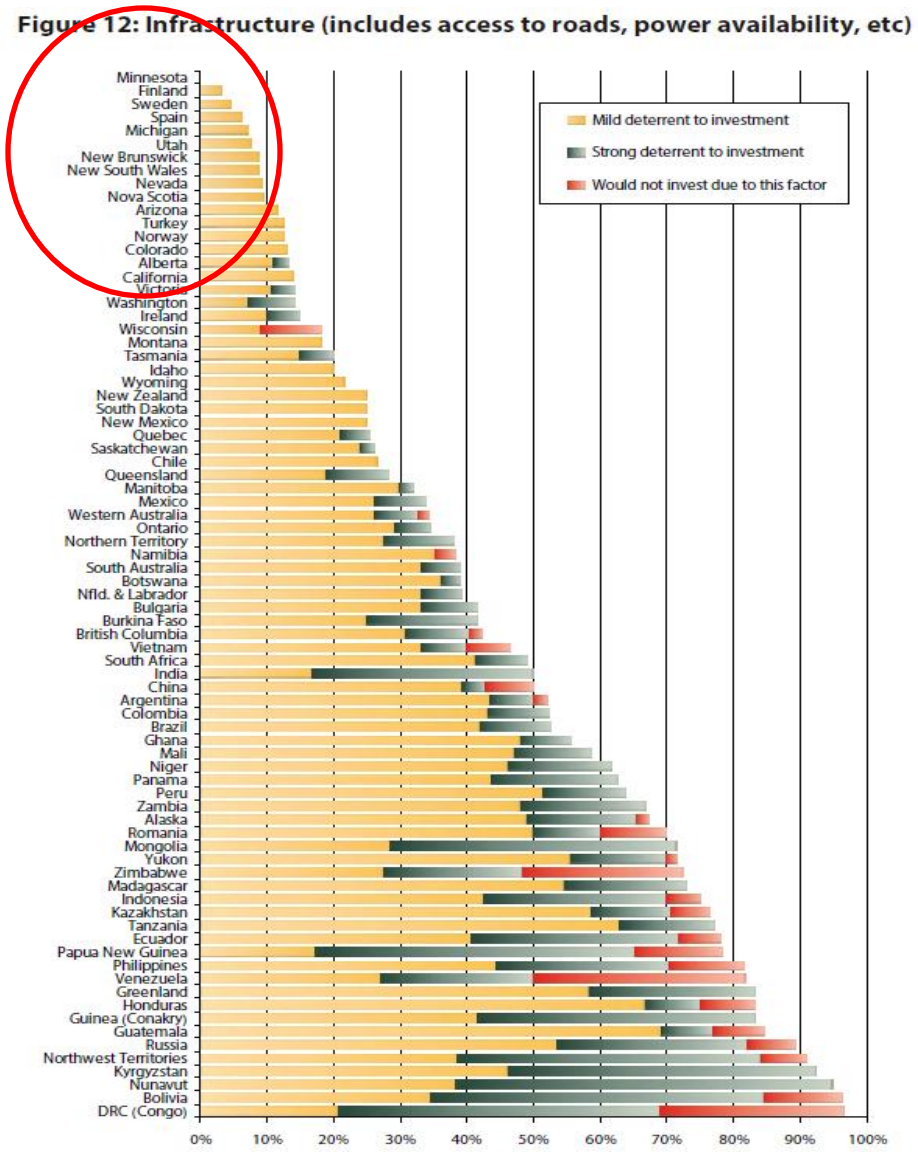
- Relatively higher risk of supply disruption due to uncertainty over the rules
  - Regulations
  - Taxes and royalties
  - Property rights and basic rule of law
- Relatively higher risk of industrial action, labor action or nationalization
- Technology transfer and loss of know-how
- Loss of key links in the middle of the supply chain
  - The U.S. has mineral wealth, it just chooses to limit its use
  - Policy-driven or basic economics?

Fraser Institute Policy Potential Index 2010/2011: Some U.S. states are not friendly to Mining

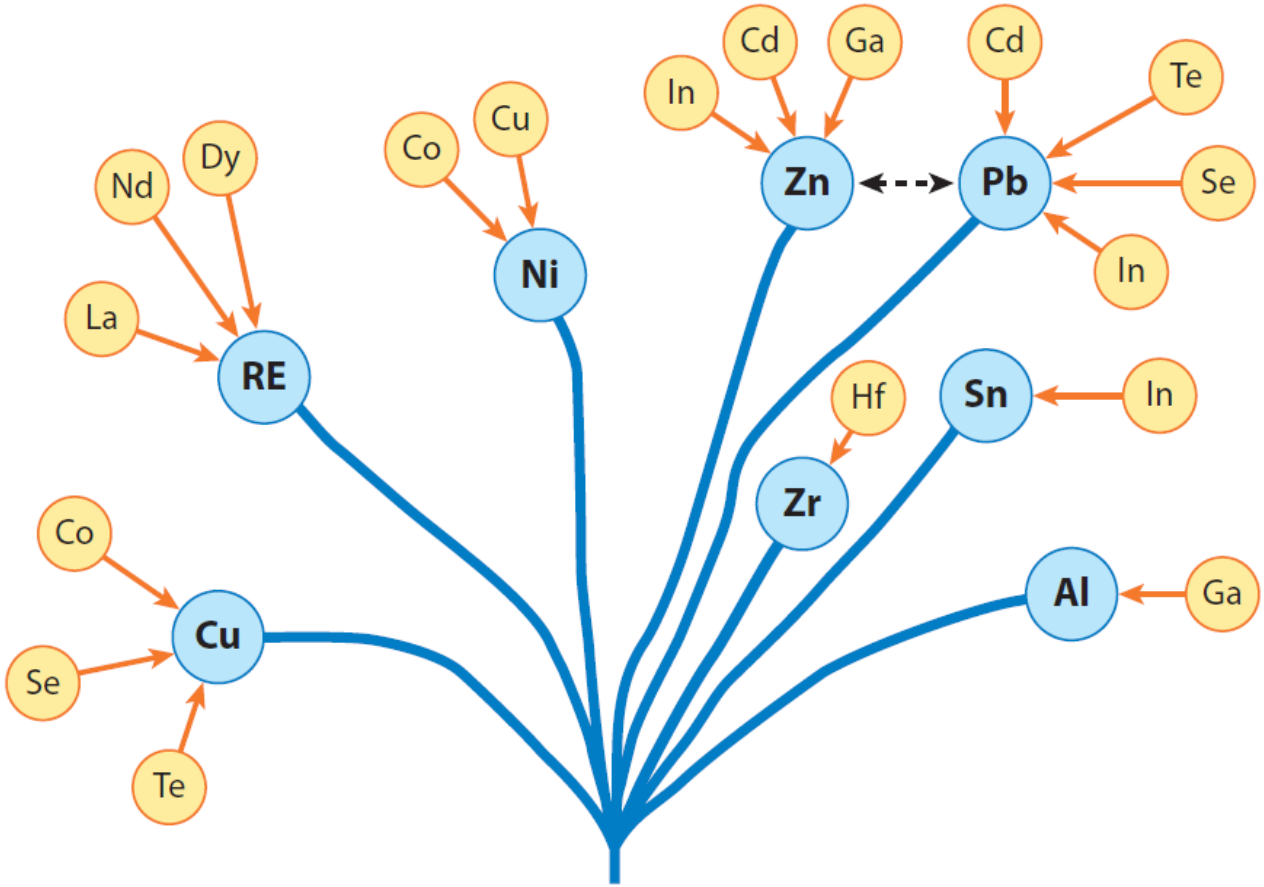
Figure 6: Uncertainty concerning environmental regulations



Fraser Institute Policy Potential Index 2010/2011: U.S. Fares Better in Land Issues



Parent/Daughter Metals Complicate Economics

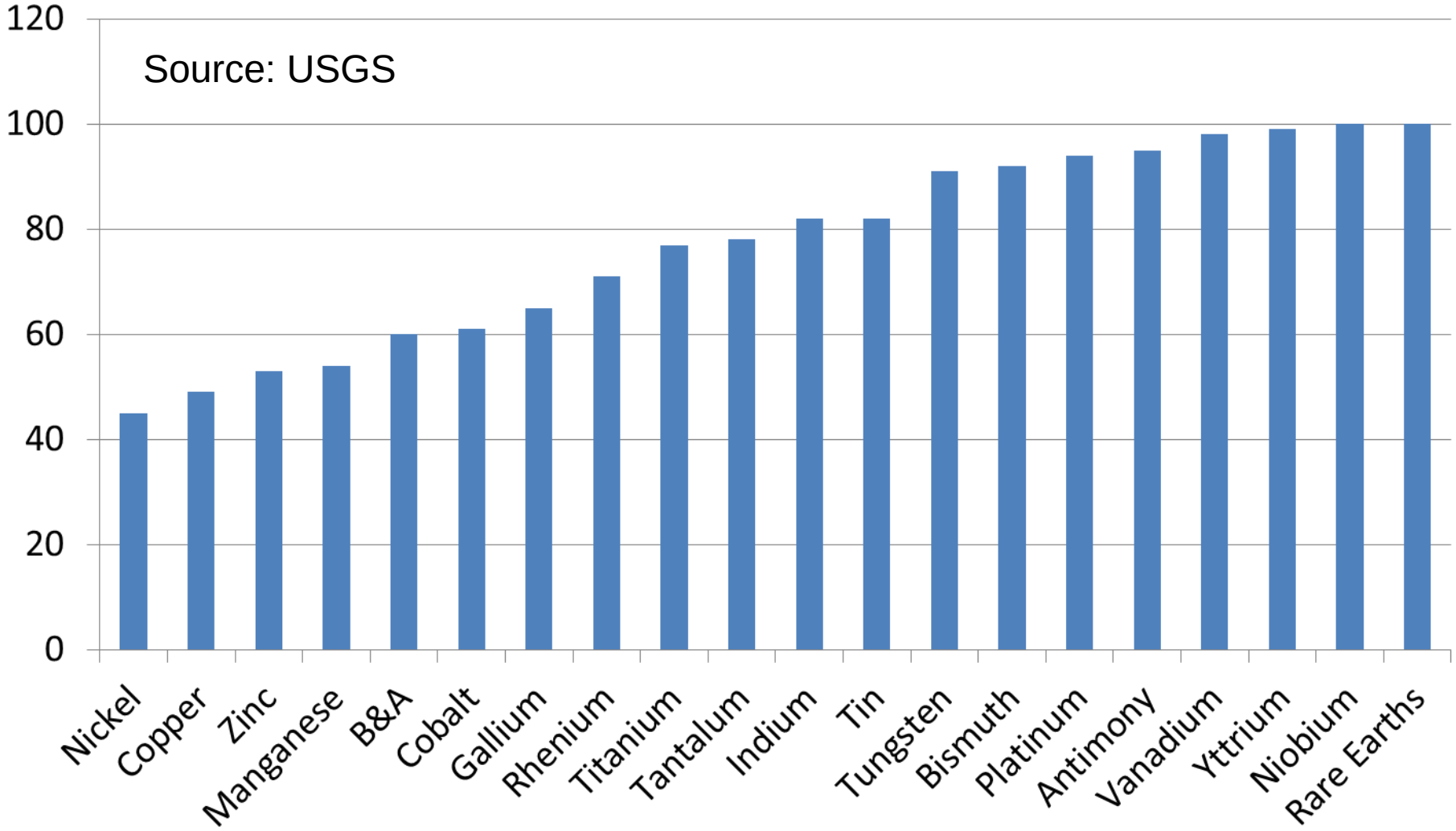


Source: Adapted from Hagelüken & Meskers courtesy of Professor Graedel

Market Concentration

- Typical measures
  - Herfindahl-Hirschman Index (HHI)
  - Concentration ratios
    - Share of world production
    - Share of U.S. imports
- Market share of top 3 supplier countries
  - Antimony – 94%
  - Bismuth – 90%
  - Niobium – 100%
  - Rare earths - ~100%
  - Rhenium – 68%
  - Zinc – 66%
- Companies that operate in highly concentrated markets can wield enormous power
  - Pricing
  - Intellectual property
  - Raw material negotiations
  - Barriers to entry

Market Share of Top 3 Producing Countries



Prices

- Serve as signals that allocate resources and reveal consumer preferences
- Are more transparent in exchange traded commodities such as LME and COMEX
- Spikes can show response to unusual supply disruptions, government policy or demand excursions
  - Political upheaval in the DRC in the 1990s (cobalt)
  - Supply disruption in 2007-2008 (silicon wafers, spot price)
  - Reduction of Chinese export quotas (rare earths)
  - Laptops (1996) and flat screens (2005) (indium)

Bringing it all Together

- The objective is to get some measure of risk
  - Importance to the industrial base
  - Vulnerability of supply
- Develop techniques to plot risk on a matrix
  - 2 dimensional
  - 3 dimensional (adding environmental risk to demand and supply risk)
  - Other dimensions?

Food for Thought

- Digital “additive” manufacturing
- 3-D printing
- Replication
  - Spare parts market
- China’s so-called labor cost “advantage”
- Carbon Fibers/Composites
- Viruses (the good kinds) and nanotechnology

Thank You!

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DEFENSE LOGISTICS AGENCY

AMERICA'S COMBAT LOGISTICS SUPPORT AGENCY